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Weed suppression and nitrogen availability using different green manure crops /

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WEED SUPPRESSION AND NITROGEN AVAILABILITY USING DIFFERENT GREEN MANURE CROPS

A Thesis Presented

by

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ABSTRACT

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USING DIFFERENT GREEN MANURE CROPS

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Cover crops are frequently used alternately with a main crop in order to add organic matter to the soil, suppress weed production, inhibit nutrient loss due to erosion, and, in the case of legume cover crops, add nitrogen to the soil. Farmers often plant a cover crop to meet one of the first three needs without regard to the effect of the cover crop on soil nitrogen. A two-year trial study examined weed suppression and nitrogen contribution of medium red clover (*Trifolium pratense* L.), alsike clover (*Trifolium hybridum* L.), ladino clover (*Trifolium repens,* L.), hairy vetch (*Vicia villosa* Roth), tricale (*Lolium multiflorum,* L.) and field pea (*Pisum arvense* L.) in combination, winter rye (*Lolium multiflorum* Lam), and winter rye combined with medium red clover, ladino clover, and hairy vetch. In the second year, all treatments were grown with three levels of ammonium nitrate. Weed biomass, soil nitrogen, tissue nitrogen, and corn yield were compared with control groups including no green manure treatments and treatments with 84 kg ha^{-1} and 168 kg ha^{-1} ammonium nitrate. The cover crops were grown from early April until early July, at which time they were incorporated into the soil and corn was planted. Corn yield was determined at harvest in mid-September. Wet and dry weights of cover crops, weeds, marketable and non-marketable corn ears, and whole corn plants were determined. Cover crop and corn yields were substandard as compared to norms in the field. However, significantly higher nitrogen contributions were found for the legume treatments as compared to the treatments without legumes. Corn yield was significantly higher in the legume treatments and significantly lower in treatments containing ryegrass, at every level of ammonium nitrate. Ryegrass was most effective in controlling weed growth. No statistically significant difference in soil nitrogen was found for the various treatments, presumably due to the limited amount of cover crop biomass incorporated.

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CHAPTER 1

INTRODUCTION

In the northeast United States, and particularly in the Pioneer Valley, sweet corn is a very important farm crop (Sarrantonio, 1994). Sweet corn also has a very high nitrogen requirement (Cline, 1996; Ess, 1994). To meet the consumer demand for sweet corn, farmers regularly apply synthetic nitrogen fertilizer to replenish this nutrient in the soil. Also, to increase corn yield, farmers frequently apply herbicides to reduce competition from weeds.

There are numerous disadvantages to the application of synthetic nitrogen fertilizer, including the environmental costs associated with the manufacturing process and with fertilizer leaching (Stute, 1993). In addition, application of synthetic fertilizer can be both costly and time-consuming. On the other hand, there are many potential advantages to using cover crops, often called "green manures," as a nitrogen source. They reduce or avoid the environmental problems associated with synthetic fertilizers and can, depending upon the crop used, be comparable in cost (Ess, 1994). In addition, they can add organic matter to the soil, improving soil health while providing needed nutrients (Jannick, 1996).

Farmers and researchers know well the advantages of green manures in improving and maintaining soil fertility. In 1921, Harlan wrote:

> The plowing under of green crops for the purpose of maintaining the fertility of the soil is almost as old as history itself. The ancient nations compelled to live for centuries upon the same land, realized the importance of green manure crops often to a fuller degree than do we the inhabitants of our relatively new country. Here the problem of maintaining soil fertility is only beginning to be so serious as to call for the development of the best farm practices with reference to the use of these green manure crops.

Using cover crops, instead of herbicides, to reduce competition from weeds has similar advantages. There have been several concerns raised regarding the use of herbicides because of problems associated with migration of the herbicides into local aquifers (Stute, 1993). It is also expensive for farmers to apply herbicides. However, if weed competition is not suppressed, it becomes difficult for farmers to obtain an adequate corn yield (Swanton, 1996). It is therefor important to conduct research into possible alternatives to the use of herbicides. If these alternatives can also provide other important benefits to the farmer, such as improving soil fertility, they become more cost effective and attractive.

Numerous research projects have been conducted in the Northeast and elsewhere looking at the efficacy of various green manure crops in improving soil quality, subsequent crop production, and weed control (Biederbeck, 1996; Holderbaum, 1990; Lichtenberg, 1994). These studies used over-wintering green manure crops and, in the case of a corn primary crop, an early summer planting of corn. Since farmers often desire to have fresh sweet corn available in the fall, an experiment was designed to determine whether species sometimes used as cover crops could be used to supplement or supplant nitrogen fertilizer and alleviate weed competition when seeded in the spring for a late summer corn crop.

CHAPTER 2

LITERATURE REVIEW

Biological nitrogen fixation by legumes

The phenomenon of biological nitrogen fixation, that is, the capacity of some microorganisms to convert atmospheric nitrogen to a form usable and accessible to plants, is a very crucial part of the process of maintaining the nitrogen balance in soil. These microorganisms are particularly effective in fixing atmospheric nitrogen, which is useful in an agricultural system, when they have entered into a symbiotic relationship with a plant (VanRhijn, 1995). While not all plants are capable of harboring these bacteria, most members of the legume family are able to enter into symbiosis with nitrogen-fixing bacteria (Loomis, 1992).

There has been a great deal of research on the nitrogen-fixing capabilities of various leguminous cover crops (Ledgard, 1996; Jannick, 1996; Guldan, 1996). While much of this research is recent, with the renewed interest in alternatives to synthetic nitrogen fertilizers, the benefits of legumes to an agricultural system have been long known. The Chinese recognized the value of companion crops as sources of nutrients as long as 2000 years ago, when they documented the benefits of planting *Azolla* in rice fields (Paul, 1989). In the early 1800's, records show that Europeans planted peas and beans in rotation with wheat, or planted white clover at the end of the growing season, in order to take advantage of the nitrogen-fixing capacity of the legumes (Paul, 1989).

Legumes can, by developing a symbiotic relationship with nitrogen-fixing rhizobium bacteria in the soil, effectively use nitrogen which is taken from the atmosphere by these bacteria and made available for the plant's use (vanRhijn, 1995). While "rhizobium" is the common term used to characterize nitrogen-fixing bacteria, they generally fall into two groups, the *Rhizobium* and the *Azobacter*, the former being first isolated in 1888 and the latter in 1901 (Salisbury, 1985). Generally, a particular rhizobium strain can enter into a symbiotic relationship with only one or a few plant species, usually legumes (Salisbury, 1985). For this reason, it can be necessary to inoculate the seeds of a crop with the bacteria before planting if that plant species has not been in the soil for a few years. While rhizobium are able to live freely in the soil, if not in the protection of a plant's roots they are subject to intense competition from the large number of other soil microorganisms (Rao, 1984). In addition, it has been found that strains of rhizobium that are not able to develop a symbiotic relationship with a particular crop plant are often more competitive than the host-specific strain (Rao, 1984). Inoculation is often necessary to assure adequate numbers of the useful microorganisms (Loomis, 1992).

Both groups of rhizobium contain nitrogenase, the enzyme necessary for nitrogen fixation (Paul, 1989). This enzyme is made up of two proteins, which contain sulfur, iron, and molybdenum, which are, therefore, essential for nitrogen fixation (Loomis, 1992). Because nitrogenase is denatured by oxygen, rhizobium require an anaerobic environment in order to fix atmospheric nitrogen(VanRhijn, 1995). However, the process of nitrogen fixation is extremely energy dependent, requiring more than a mole of glucose for each mole of nitrogen fixed (Loomis, 1992). Therefore, nitrogen fixation can generally occur only in an aerobic environment, where energy production is the most efficient (Postgate, 1987). In addition, it requires a healthy plant which is carrying on efficient photosynthesis, so that sufficient photosynthate can be produced to support both the plant and the nitrogen-fixing bacteria (Salisbury, 1985).

In order to meet these conflicting requirements, rhizobium have developed the capacity to enter into a symbiotic relationship with leguminous plants whereby the bacteria are allowed to enter the root hairs of the plant where the plant forms nodules, creating an anaerobic environment for the nitrogenase (Paul, 1989). These nodules, when healthy and active, are a pink color, indicating the presence of leghemoglobin, with its red heme group (Paul, 1989). It is thought that it is the leghemoglobin which transports oxygen within the nodules (Salisbury, 1985).

It is now recognized that a complex chemical mechanism is involved in the process of attraction of the bacteria to the surface of the legume and the incorporation of the bacteria into the plant (Paul, 1989). The two-way interaction between molecules produced by the plant and molecules produced by the rhizobium accounts for the host/invader specificity which limits the plants which can take advantage of the rhizobium's nitrogen-fixing talents (Paul, 1989).

Environmental factors play a significant role in the efficiency of nodulation. In particular, high levels of nitrate nitrogen in the soil can inhibit the formation of nodules in roots which would otherwise be susceptible to entering into symbiosis with rhizobia (Macduff, 1996). Temperature, density of the crop, and mineral supply in the soil (Loomis, 1992) are also implicated. While iron, sulfur, and molybdenum are considered essential because they constitute a part of the nitrogenase complex, adequate quantities of soil phosphorus, calcium, potassium, and zinc are also important for assuring normal rate of fixation (Loomis, 1992). In addition, low soil pH interferes with fixation (Loomis, 1992).

Different leguminous species differ greatly in their ability to produce nitrogen that can become available to subsequent crops (Biederbeck, 1996). Contribution of fixed atmospheric nitrogen varies depending upon the amount of nitrogen already available in the soil and the nitrogen content and dry matter accumulation of the cover crop (Holderbaum, 1990). Macduff (1996) found that nitrate availability to clovers quickly reduces nodulation. Within seven days of application of even low levels of nitrate-N, clover lost virtually all ability of fix nitrogen (Macduff, 1996). Nitrates in the soil inhibit nitrogen fixation for several reasons: they cause interference with bacterial attachment to the root hair, nodule growth, and N-fixation within nodules, as well as causing senescence of the nodules and the infection threads (Salisbury, 1985).

Most of the "fixed" nitrogen remains in the legume while the plant is alive and is released into the soil when the plant decomposes (Sarrantonio, 1994). In the case where green manure crops are to be planted alternately with the main crop, as opposed to a system of intercropping, where the main crop and the green manure are grown side-by-side, the importance of this nitrogen-fixing ability is two-fold. Firstly, the green manure crops are able to grow and develop biomass, which will add organic matter to the soil without depleting the existing nitrogen stores in the soil (Jannick, 1996, Sarrantonio, 1994). Secondly, when the green manure crop is incorporated into the soil, this incorporation may add additional nitrogen to the soil over the amounts originally available (Crozier, 1994).

Nitrogen release into the soil

Under ideal conditions, research has shown that leguminous cover crops can add as much as 130-170 kg ha^{-1} available N to the soil(Cline, 1996; Hoyt, 1986; Utomo, 1990). Others show a smaller effect of 70-85 kg ha^{-1} (Blevins, 1990; Crozier, 1994). Holderbaum (1990) estimated that hairy vetch can add as much as 2 kg ha^{-1} day^{-1} of nitrogen during the period of active growth.

When nitrogen is added to the soil as part of a decomposing plant, the nitrogen is released slowly into the soil as the decomposition progresses. For example, it is estimated that approximately one-half of the nitrogen in a legume is made available to growing plants during the first season that it is incorporated into the soil (Sarrantonio, 1994). Liu (1996) found that 70% of the nitrogen in a harvested cover crop was released within three weeks of an early June incorporation. This so-called "slow-release" characteristic is significant, because it means that, with proper soil management, nitrogen from the decaying plants can be made available to the main crop gradually, as the crop needs it (Clark, 1995). The more quickly the soil nitrogen is used after it is available, the less will be subject to leaching or denitrification (Wagger, 1988). This "slow-release" system contrasts with nitrogen fertilizer applications, which are made once or twice during the growing season in a form that is, at least at the outset, not bound up in the soil (Biederbeck, 1996). Often, before it can be fixed in the soil or used by the growing crop, the applied nitrogen is lost to leaching or denitrification (Radke, 1988).

Recently, there has been considerable research into the timing of nitrogen release from decaying green manure crops. When studying the release patterns from hairy vetch and crimson clover, Mitchell (1977) found that approximately one third of the cover-crop nitrogen was taken up by the subsequent corn crop in the first year. Biederbeck (1996), looking at four different legumes in rotation with a cereal crop, found that 20% of the cover crop nitrogen was taken up by the cereal. Both Frye

(1988) and Ebelhar (1984) found that soil nitrogen was greatly increased immediately after incorporation of leguminous cover crops, compared to normally fertilized soils, but returned to levels comparable to the fertilized soils within eight weeks after incorporation.

The extent to which incorporation of green-manure-crop residue initially increases or decreases available nitrogen is dependent upon the carbon-to-nitrogen ratio of the residue (Schoenau, 1996). Plants with high nitrogen content, like legumes, will have a carbon to nitrogen ratio of less than 30-35:1 and will release nitrogen at the outset (Schoenau, 1996; Pinck, 1948). When incorporated plant matter has a higher carbon-to-nitrogen ratio, some of the available nitrogen in the soil is taken up by microbes involved in decomposing the plant material and so is not available to growing plants (Pinck, 1948).

Soil nitrogen effects of various cover crops

Kuo (1997) studied the soil nitrogen effects of an overwinter cover-cropping with hairy vetch, Austrian winter pea, cereal rye, and annual ryegrass, followed by a summer corn crop. He found that hairy vetch contributed on the average 123 kg ha^{-1} nitrogen to the soil, and that annual ryegrass contributed, on the average, 37 kg ha^{-1} nitrogen. When correlating the nitrogen contribution with the amount of soluble carbon compounds, he found that the ratio of carbon to nitrogen was much higher in the annual ryegrass and other non-legumes than in the hairy vetch. Because of the high relative amount of nitrogen in the biomass, the legumes, and in particular the hairy vetch, were able to contribute available nitrogen to the growing corn crop much more quickly and efficiently than the non-legumes.

Ranells (1996) analyzed nitrogen contributions of cover crop combinations, again looking at fall-planted, over-wintering cover crops which were harvested in the spring, prior to a spring planting of corn. He studied hairy vetch, crimson clover, ryegrass, rye with crimson clover, and rye with hairy vetch, assessing the nitrogen content of the cover crop biomass, carbon-to-nitrogen ratios, and the resultant contribution of nitrogen to the soil over time. The legumes, in both monoculture and biculture, had a carbon-to-nitrogen ratio of less than 30:1, indicating that mineralization of nitrogen was likely to occur. Only in the rye monoculture was the ratio higher, in this case 40:1, so that net immobilization of the nitrogen would be expected.

Analyzing the decomposition rates of the various cover-crop treatments used, Ranells (1996) found that the rate of decomposition and release of usable nitrogen to the soil were closely correlated with the carbon-to-nitrogen ratio of the cover crop incorporated. The higher the carbon-to-nitrogen ratio, the slower the decomposition and nitrogen release. However, with successive additions of plant residues to the soil, there will be eventual release of nitrogen and an increase in nitrogen available to crops (Pinck, 1948).

Advantages of cover crops

Researchers have found that legume cover crops have value to the soil beyond the addition of usable nitrogen in the short term. Elbahar (1984) found the benefit of hairy vetch increased yearly over a five-year period, which he attributed to both a build up of soil nitrogen and a change in the physical properties of the soil. Mitchell (1977) saw a benefit from the use of a hairy vetch that lasted four years past the use of the crop attributed to a slow release of nitrogen to the soil and a reduction in loss from leaching. McKenney (1993) found that the additional organic matter in the soil due to use of a cover crop increased the ability of the soil to bind residual nitrogen for use by crops in subsequent seasons.

The use of cover crops benefits the soil in a variety of ways. The water retention ability of the soil can be greatly increased, leading to less water stress on the subsequent crop (Holderbaum, 1990; Tyson, 1990; Ebelhar, 1984) and less erosion (Biederbeck, 1996). Further, the organic matter binds the nitrogen, so less is leached out of the soil (Mitchell, 1977; Radke, 1988). Also, the soil is less compact, with better aeration (Abdul-Baki, 1996; Stevenson, 1996). Further, there may be less competition from weeds, so the nutrients are available to the crop (Stevenson, 1996; Swanton, 1996; Putnam, 1986).

Tyson (1990) also found an interesting effect of leguminous cover crops on microbial activity. He studied corn grown in soils that had or had not previously grown a legume (in this case, alfalfa) and found that the soils that previously supported a legume crop had significantly increased growth of vesicular arbuscular mycorrhizal fungi, which increased the capacity of plants to draw phosphorus from the soil. Stevenson (1996) also found increased availability of phosphorus, potassium, and sulfur in soils with leguminous cover crop applications.

Weed suppression

There has been considerable research into the efficacy of various cover crops as weed suppressants (Barnes, 1986). Plants interfere with the growth of neighboring plants both by competition, where a more hardy or faster-growing plant is able to seize a large percentage of the soil nutrients, water, and light from competing plants, and by direct chemical suppression

(Putnam, 1986). Another mechanism for weed suppression is termed "allelopathy," which describes a phenomenon whereby plants excrete substances to inhibit the growth of competing plants (Putnam, 1986).

Crops which develop a sizeable biomass, such as annual ryegrass or cereal rye, will show the greatest allelopathic strength, since there is a threshold level of allelochemicals necessary for the effect to take place (Einhellig, 1986). In his research, Einhellig (1986) found it difficult to determine the precise physiological mechanism of allelopathy, but concluded that it functions by reducing the chlorophyll content of competing plants. Often there is also interference with nutrient and water uptake (Einhellig, 1986).

It has been shown by researchers that annual ryegrass and cereal rye allelopathically inhibit the growth of many weed species (Smith, 1994). This is true when the annual ryegrass is planted in the spring and plowed under in mid-summer and when cereal rye is planted in the later summer and allowed to over-winter (Barnes, 1986). The allelopathic reaction also appears to be effective both when the cereal rye is actively growing and when it has been incorporated into the soil and is decomposing (Mangan, 1995). Annual ryegrass is also early to germinate and a very quick-growing plant, quickly gaining considerable mass and, thereby, a competitive advantage (Sarrantonio, 1994).

Because of these traits, it would be expected that cereal rye and ryegrass would competitively inhibit the growth of other plants as well. Stewart (1996) found that there was a decrease in the growth of white clover when grown with perennial ryegrass, and that the more nitrogen that was added to the system, the greater the competitive advantage of the ryegrass, since the added nitrogen encouraged faster ryegrass growth.

Clovers and other legumes are also able to inhibit competitive growth allelopathically (Bradow, 1993). However, they are not quick to germinate (Sarrantonio, 1994), and weeds may become well established before they are able to slow or stop their growth. In addition to their allelopathic behavior, clovers and other legumes appear to develop strong and pervasive root systems and a dense foliage cover, which may act to suppress competition once the legume is firmly established (Infante, 1996).

It can be difficult to maintain the necessary balance between weed suppression and nitrogen availability when establishing a cover-cropping system which attempts to alleviate the need for either synthetic fertilizer or herbicides. While ryegrass appears to have advantages in weed suppression over leguminous crops because of its quick germination, accumulation of biomass, and allelopathic characteristics, it is unable to enter into a symbiotic relationship with bacteria which fix nitrogen (vanRhijn, 1995), so whatever nitrogen it may add to the soil upon decomposition must necessarily have been originally taken from that same soil.

Because ryegrass takes its nitrogen from the soil, using ryegrass alone as a green manure will not add available nitrogen to the soil. In addition, it has been found that the use of ryegrass as a green manure can make nitrogen less available to subsequent crops, because, while decomposing, the ryegrass will immobilize soil nitrogen, whether made available by application of synthetic fertilizers or by simultaneously-growing nitrogen-fixing cover crops (McKenney, 1995). So, even though a ryegrass green manure will add organic matter to the soil and have some weed-suppressing potential, it will require the addition of nitrogen to the soil to counteract the effect of the nitrogen immobilization (Holderbaum, 1990).

While use of grasses as cover crops in conjunction with a legume is a short-term disadvantage for availability of soil nitrogen, it can have long-term advantages, because the grass acts as sink for residual nitrogen in the soil (Wagger, 1998). Since only a small portion of the nitrogen in leguminous cover crops is used by succeeding crops in the first year (Biederbeck, 1996), immobilization of the residual nitrogen in ryegrass will preserve it in the soil rather than depleting it through leaching (Wagger, 1998).

Objectives

The objectives of this study were to examine the efficacy of various green manure systems, seeded in the spring, with a mid-summer planting of sweet corn. The green manure systems used legumes to take advantage of their nitrogen-fixing capabilities, and when combined with annua ryegrass, to act as a nitrogen sink and weed suppressant. The effectiveness of the treatments was measured by the growth of the corn in the various plots.

CHAPTER 3

MATERIALS AND METHODS

The experiment was performed during two growing seasons, April through September, of 1996 and 1997, at the University of Massachusetts South Deerfield Research Farm in South Deerfield, Massachusetts. The soil type throughout was a Hadley fine sandy loam (coarse, mixed, Fluventic Dystrocrept).

The 1996 experiment contained twelve treatments:

1. Medium red clover (*Trifolium pratense* L.) seeded at a rate of 22.5 kg ha^{-1}.

2. Ladino clover (*Trifolium repens* L.) seeded at a rate of 11.2 kg ha^{-1}.

3. Alsike clover (*Trifolium hybridum* L.) seeded at a rate of 11.2 kg ha^{-1}.

4. Hairy vetch (*Vicia villosa* Roth) seeded at a rate of 33.6 kg ha^{-1}.

5. Annual ryegrass (*Lolium multiflorum* Lam) seeded at a rate of 33.60 kg ha^{-1}.

6. Annual ryegrass (*Lolium multiflorum* Lam) seeded at a rate of 11.2 kg ha^{-1} combined with medium red clover (*Trifolium pratense* L.) seeded at a rate of 22.50 kg ha^{-1}.

7. Annual ryegrass (*Lolium multiflorum* Lam) seeded at a rate of 11.2 kg ha^{-1} combined with ladino clover (*Trifolium repens* L.) seeded at a rate of 11.2 kg ha^{-1}.

8. A premixed combination marketed by Agway Corporation as Tripper Mix of triticale (*Triticosecale* Wittm.) and field pea (*Pisum arvense* L.) seeded at a rate of 168 kg ha^{-1}.

9. Annual ryegrass (*Lolium multiflorum* Lam) seeded at a rate of 33.6 kg ha^{-1} followed by an application of ammonium nitrate fertilizer at a rate of 168 kg ha^{-1} nitrogen.

10. A control plot with no cover crop grown followed by an application of ammonium nitrate fertilizer at a rate of 168 kg ha^{-1} nitrogen.

11. A control plot with no cover crop grown followed by an application of ammonium nitrate fertilizer at a rate of 84 kg ha^{-1} nitrogen.

12. A control plot with no cover crop grown and no subsequent ammonium nitrate application.

The experimental design was a randomized complete block with four replications. Plots measured 2.5 meters by 7.5 meters. Identical treatments had been used on these same plots the previous growing season, so no innoculants were used. The cover-crop treatments were seeded on 19 April 1996. Starting on 14 May 1996, and weekly thereafter, the percentage ground cover of weeds and cover crops in each plot was assessed visually. Aside from this visual assessment, the cover crops were permitted to grow without interference until 8 July 1996.

At that time, a section of each plot 0.6 m by 0.6 m was clear-cut to the soil surface and the plant material obtained was separated into cover crop or weed portions. In the case where more than one cover crop was seeded, these cover crops were separated. Fresh weights and dry weights were obtained for each plant sample. Nitrogen content of the cover crop biomass was analyzed using the Kjeldahl method (Bradstreet, 1965).

In this method, the plant material is dissolved in sulfuric acid. The tissue nitrogen forms an ammonium salt. The solution containing the ammonium salt is distilled into boric acid plus indicator solution, which traps the ammonium. This solution is then titrated with a solution of 0.0143 M potassium biiodate. The measurement of ammonium is an indicator of the total nitrogen in the plant sample (Bradstreet, 1965).

On 10 July 1996, the plots were plowed under and sweet corn was planted. The cultivar Harmony was chosen because it is fast-growing and generally has consistent germination. Corn was planted in three rows per plot, length-wise down the plots, in rows 0.75 m apart. Plants were thinned to one plant per 0.3 m. On 29 July 1996, potassium was added in accordance with soil test data obtained from a soil test of the entire experiment area performed on 3 May 1996 by the Soil and Plant Tissue Testing Lab, West Experiment Station, University of Massachusetts. Ammonium nitrate was applied to the annual ryegrass plots as a side dressing on 5 August 1996, when the corn plants were 0.3 meters tall, in accordance with the experimental design.

The corn was harvested on 25 September 1996, by cutting ten plants in the middle of the middle row of each plot. The number and fresh weight of marketable and non-marketable ears were ascertained as was the fresh weight of the stover. The cut material was subsequently dried for three days at 93 C and a dry weight obtained.

In 1997, the experiment was moved to a new area within the University of Massachusetts South Deerfield Research Farm. In this second year, a 4 X 2 X 3 factorial design was used, in a randomized complete block design, with four replications. The plot size was 2.5 meters by 7.5 meters.

Legume treatments factors included: medium red clover seeded at a rate of 22.5 kg ha^{-1}, ladino clover seeded at a rate of 11.2 kg ha^{-1}, hairy vetch seeded at a rate of 33.6 kg ha^{-1}, and a control without a legume cover crop. Grass treatment factors included annual ryegrass seeded at a rate of 11.2 kg ha^{-1}, and a control with no ryegrass cover crop. Nitrogen treatment factors included 0, 78, and 156 kg ha^{-1} applied as side dressing when the corn plants reached a height of 0.3 meters.

The cover crop treatments were applied on 29 and 30 April 1997, later than the previous year because wet conditions precluded plowing earlier in the season. Because these were new sites, innoculants were applied with the legume treatments. Plant samples were taken from an area 0.6 m by 0.6 m on 11 July 1997, the samples then separated into the weed portion and the cover-crop portion. Where both a ryegrass and legume cover crop were seeded, they were separated at sampling. Each portion of the biomass was then weighed fresh, dried for three days at 93 C, and weighed again.

The cover crops were plowed under on 14 July 1997, and corn was planted on 15 July 1997. Again, the cultivar Harmony was used, and it was planted and thinned in the same manner as in 1996. Side-dressed ammonium nitrate was applied on 11 August 1997, when the plants were approximately 0.3 meters tall, at the three levels described above. The corn was harvested on 23 and 24 September 1997, using the same methods as were employed the previous year.

Plant samples from both years were tested for total nitrogen content using the Kjeldahl method of nitrogen analysis described above. Soil samples were taken from each plot, during the second year of the experiment, on 19 May 1997, prior to substantial growth of the cover crops, on 11 August 1997, prior to the side-dressing of the ammonium nitrate, and again on 25 September 1997, subsequent to the corn harvest.

The soil samples taken on 11 August 1997 only were analyzed using the Technicon AutoAnalyzer II (Technicon Industrial Systems, Tarrytown, N.Y.), an automated system for measuring nitrate-N in a solution. The soil nitrate is extracted using a solution of calcium sulfate. The nitrate in the solution is reduced in a copper-cadmium reductor column and then reacts with sulfanilamide to form a diazo compound which, upon further reaction, will form a reddish color. The depth of the color is then read to determine the original amount of nitrate in the solution (Technicon, 1973).

CHAPTER 4

RESULTS-1996

The cover crops were seeded in early April and all germinated and grew normally. By the time the clover plants had attained enough growth to assess ground cover meaningfully, the ryegrass growth was substantial. On 28 May, the first date of ground-cover assessment, the clovers and vetch covered between 6% and 14% of the soil surface (Table 1). Those treatments with ryegrass or triticale had significantly more coverage (30-45%). On 11 June, there was still a significant difference between the coverage of the legumes, the vetch and clovers, and the grains, the former covering 23% to 41%, the latter covering 70% to 85%. By 25 June, there were still significant differences between the ground covers; however, the hairy vetch growth was strong enough that there was no longer a significant difference between the ground cover of the vetch and of the three grain and legume mixtures (Table 1). The ryegrass alone continued to be a more effective cover than the others. By 9 July, before the cover crops were plowed under, all showed a coverage between 78% and 93% and there was no statistical difference between them (Table 1).

The amount of weed invasion was negatively related to the rate of ground-cover development (Table 2). While all treatments significantly suppressed weed growth, those that contained grasses were significantly more successful. Untreated plots had 1490 kg ha^{-1} hectare weed dry weight by 9 July, whereas ryegrass treatments had only 64 kg ha^{-1}. The legume treatments without grasses contained 504 to 890 kg ha^{-1} weed dry weight.

Table 2 also shows the total dry weight of the cover crops. The triticale and field pea mixture produced 3780 kg ha^{-1} total dry weight. The legumes alone produced 1100 to 1470 kg ha^{-1} dry weight, significantly less than any of the legume and grass mixtures.

The percentage nitrogen in the hairy vetch was 4.1% (Table 3), significantly higher than in any other cover investigated. The ryegrass, whether or not grown in plots which had been given previous nitrogen treatments and whether or not grown with legumes, had 1.1 to 1.8% (Table 3). In addition, the existence of grasses did not make a significant difference in the percentage nitrogen in the tissues of the legumes. All legume treatments except hairy vetch were 2.6 to 2.9% nitrogen (Table 3).

The total nitrogen per hectare contributed was the most for the triticale/field pea mixture (Table 3). The vetch treatment contributed somewhat less than the triticale and sweet pea combination, at 60 kg ha^{-1}, and the remainder of the treatments were statistically indistinguishable, ranging from 24 to 44 kg ha^{-1}. Table 3 also shows the legume nitrogen contribution alone. The hairy vetch and field pea treatments contributed 60 and 53 kg ha^{-1} respectively, which was significantly greater than the other treatments, which contributed 18-37 kg ha^{-1}. The legumes grown with ryegrass contributed approximately 20 kg ha^{-1} nitrogen compared to those grown without ryegrass, which contributed about 35 kg ha^{-1}.

The total dry weight of the above-ground portion of the corn plots under the various treatments is shown in Table 4. The greatest total yield was obtained in the plots which contained hairy vetch, ladino clover, and the field pea-triticale mixture. These ranged from 4600 to 4940 kg ha^{-1}. The treatments which had ryegrass produced significantly less, even when combined with nitrogen fertilizer or legumes.

Production of corn ear dry weight was also lower in those plots which contained ryegrass, while there was no evidence of an advantage of the use of leguminous crops over nitrogen fertilizers (Table 4). Marketable yield, however, was greatest with hairy vetch, ladino clover, and the triticale/field pea mixture (Table 4).

Table 1. Percent coverage of the soil surface by several cover-crop treatments. All cover crops were seeded on 19 April 1996.[z]

Treatment	14 May	28 May	11 June	25 June	8 July
Hairy Vetch	1	6 c	23 d	71 bcd	92
Ryegrass	5	43 a	85 a	90 a	88
Ryegrass/red clover	4	45 a	80 ab	86 ab	93
Ryegrass/ladino clover	3	30 b	80 ab	86 ab	93
Alsike clover	1	14 c	24 d	45 e	78
Medium red clover	2	8 c	41 c	64 d	89
Ladino clover	1	7 c	38 c	69 cd	89
Triticale/sweet pea	9	38 ab	70 b	83 abc	84
No cover[y]	2	9	49	69	83

[z]Mean separation within columns by Duncan's New Multiple Range Test (P= 0.05).
[y]"No cover" assessments included weed cover only, and therefore were not included in the statistic analyses.

Table 2. Above-ground total dry weight of cover crops and weeds of several cover crop treatments. Cover crops were planted on 19 April 1996 and sampled on 8 and 9 July 1996.

	Dry weight kg ha^{-1}			
Treatment	grass	legume	weeds	total
Hairy Vetch[x]		1470 ab	750 bc	2220 bc
Ryegrass	2050		60 e	2110 bc
Ryegrass/red clover	1530	830 cd	240 de	2600 b
Ryegrass/ladino clover	1610	680 d	260 de	2550 b
Alsike clover		1100 bcd	890 b	1990 bc
Medium red clover		1390 abc	500 cd	1890 bc
Ladino clover		1290 bcd	850 bc	2140 bc
Tricale/field pea	1940	1930 a	80 e	3950 a
No cover			1490 a	1490 c

[x]Mean separation within columns by Duncan's New Multiple Range Test (P=0.05). Means followed by the same letter are not significantly different at P=0.001.

Table 3. Above-ground total nitrogen content and nitrogen contribution of cover crops and weeds of several cover crop treatments. Cover crops were planted on 19 April 1996 and sampled on 8 and 9 July 1996.

Treatment	Percent N		N contribution (kg ha^{-1})		
	grass	legume	grass	legume	total
Hairy Vetch[x]		4.1 a		60 a	60 b
Ryegrass	1.1 b		24 b		24 c
Ryegrass/red clover	1.4 b	2.7 b	22 b	22 c	44 bc
Ryegrass/ladino clover	1.3 b	2.6 b	21 b	18 c	39 c
Alsike clover		2.9 b		31 c	31 c
Medium red clover		2.7 b		37 bc	37 c
Ladino clover		2.9 b		36 bc	36 c
Tricale/field pea	2.6 a	2.7 b	35 a	53 ab	88 a

[x]Mean separation within columns by Duncan's New Multiple Range Test (P=0.05). Means followed by the same letter are not significantly different at P=0.001.

Table 4. Above-ground total dry weight and yield of sweet corn planted after several cover-crop treatments. Cover crops were planted on 19 April 1996 and incorporated on 9 July 1996. Corn was seeded on 10 July 1996 and harvested on 25 September 1996.[z]

Treatment	Dry weight (kg/ha) Total	Dry weight (kg/ha) Ears	Yield of marketable ears (no./ha)
Hairy Vetch	4910 a	2890 a	34800 a
Ryegrass	1460 g	600 c	2800 c
Ryegrass + 156 kg ha^{-1} N	2630 f	1560 b	12000 b
Ryegrass/red clover	2990 ef	1750 b	12900 b
Ryegrass/ladino clover	3120 eg	1760 b	9500 bc
Alsike clover	4200 bc	2370 ab	17300 b
Medium red clover	3480 de	1970 b	17500 b
Ladino clover	4940 a	2860 a	28700 a
Triticale/sweet pea	4600 ab	2860 a	32700 a
No cover	3460 de	1840 b	11400 bc
No cover + 78 kg ha^{-1} N	3840 cd	2050 ab	18600 b
No cover + 156 kg ha^{-1} N	3770 cd	2210 ab	18100 b

[z]mean separation within columns by Duncan's New Multiple Range Test (P= 0.05).

CHAPTER 5

RESULTS – 1997

The growth of the cover crops in 1997 was impacted by a wet spring, which delayed plowing and planting, and a dry May, which slowed growth. There was no statistically significant difference between the growth of the different legumes, but there was a statistically significant difference between the growth of treatments with and without annual ryegrass, as is shown in Table 5. In addition, there was significantly more ryegrass in the plots without a legume.

There was a significant difference between the weed growth in the plots which contained ryegrass and those which did not, regardless of the legume treatment (Table 5). There were no significant differences in the weed growth among the plots which contained legumes. There were also no statistically significant interactions between treatments based on cover crop type, levels of nitrogen, and addition or absence of ryegrass.

The nitrogen content of the cover crops and nitrogen contributions (Table 6) revealed that hairy vetch had the highest percentage nitrogen and the highest nitrogen contribution. The nitrogen contribution of the cover crops was not increased by the addition of ryegrass, even when the nitrogen content of the ryegrass was considered a nitrogen contribution. In the case of hairy vetch, because of the high percentage nitrogen in the plant tissue and the reduction in vetch biomass with the addition of ryegrass, the addition of ryegrass markedly decreased total nitrogen contribution.

There was no statistically significant difference found between levels of soil nitrogen in the various treatments taken on 11 August 1997 (Table 7).

Table 8 shows the total yield of corn in various treatments. There were no significant differences among the legumes treatments; however, all resulted in higher corn yields than the plots without legumes. Among the different levels of ammonium nitrate applied, there was no significant difference between the plots which were given ammonium nitrate and both of these treatments had higher corn yields than the treatments which were given no additional fertilizer. In addition, those plots which had ryegrass treatments had significantly less corn growth than those without.

Also in Table 8 is the yield of marketable ears for each treatment. The yield among the legumes treatment ranged from 17200 to 19600 ears per ha $^{-1}$ and were not significantly different from each other. The yield in the treatments which did not contain legumes were significantly less than the others. Similarly, the yield in those plots which received no ammonium nitrate were significantly less than those that received ammonium nitrate; the yields in the plots which received the two different levels of ammonium nitrate were statistically indistinguishable.

Table 5. Above-ground total dry weight of cover crops and weeds of several cover crop treatments. Cover crops were planted on 29 April 1997 and sampled on 11 July 1997.

	Dry weight kg ha^{-1}			
Treatment	grass	legume	weeds	total
Hairy vetch[x]		2203 a	599 bc	2802
Hairy vetch/ryegrass	1030 b	1136 bc	201 c	2367
Red clover		1731 ab	790 b	2521
Red clover/ryegrass	1070 b	1115 bc	252 c	2437
Ladino clover		1272 bc	819 b	2091
Ladino clover/ryegrass	1190 b	670 c	206 c	2066
Ryegrass	1870 a		188 c	2058
No cover			1978 a	1978 ns
Ryegrass[z]		990	220	
		**	***	
No ryegrass		1740	1050	

[x]Mean separation within columns by Duncan's New Multiple Range Test (P=0.05). Means followed by the same letter are not significantly different at P=0.001.

[z]Ryegrass treatment means separated within column by F test.

***, **: Significant at P=0.001 or P=0.01 respectively.

Table 6. Above-ground total nitrogen content and nitrogen contribution of cover crops and weeds of several cover crop treatments. Cover crops were planted on 29 April 1997 and sampled on 11 July 1997.

	Percent N		N contribution (kg ha^{-1})		
Treatment	grass	legume	grass	legume	total
Hairy Vetch[x]		3.0 a		67.2 a	67.2 a
Hairy vetch/ryegrass	1.1 c	3.1 a	10.3 b	35.4 b	45.7 b
Medium red clover		2.1 b		45.0 b	45.0 b
Red clover/ryegrass	1.0 c	2.1 b	10.3 b	22.9 bc	33.2 b
Ladino clover		2.1 b		24.6 bc	24.6 b
Ladino clover/ryegrass	1.1 c	2.2 b	12.9 b	15.0 c	27.9 b
Ryegrass	1.0 c		18.5 a		18.5 b
Ryegrass[z]		2.5			31.6
		ns			*
No ryegrass		2.4			45.6

[x]Mean separation within columns by Duncan's New Multiple Range Test (P=0.05). Means followed by the same letter are not significantly different at P=0.001.

[z]Ryegrass treatment means separated within column by F test.
*, ns: Significant at P=0.05 or non significant, respectively.

Table 7. Soil nitrate N in samples taken at a depth of 0-10 cm. on 11 August 1997. Differences were non significant.

Treatment	Soil nitrate (mg kg^{-1})
Hairy Vetch[x]	16.3
Medium red clover	11.3
Ladino clover	12.9
No legume	10.1
Ryegrass	11.1
No ryegrass	14.2

Table 8. Above-ground total dry weight and yield of sweet corn planted after several cover-crop treatments. Cover crops were planted on 29 April 1997 and incorporated on 14 July 1997. Corn was seeded on 15 July 1997 and harvested on 23 and 24 September 1997.

Treatment	Dry Weight (kg/ha) Total	Dry Weight (kg/ha) Ears	Yield of marketable Ears (no./ha)
Hairy Vetch[X]	3270 a	1180 a	19600 a
Medium red clover	3170 a	1060 a	19200 a
Ladino clover	3100 a	1050 a	17200 a
No legume	2360 b	770 b	8800 b
Ryegrass[Y]	2810 b	930 b	14200
	*	**	ns
No ryegrass	3140 a	1090 a	18200
N application rate[Z]			
0 kg N/ha	2440 b	690 b	6200 b
78 kg N/ha	3280 a	1210 a	21100 a
156 kg N/ha	3210 a	1140 a	21300 a
significance	L** Q*	L** Q**	L** Q*

[X]Legume treatment means separated within column by Duncan's New Multiple Range Test (P= 0.05).

[Y]ryegrass means separated by F test.

[Z]Mean separation among nitrogen rates by orthogonal polynomial comparisons.

***,**,*,ns: Significant at P=0.001, P=0.01, P=0.05, or nonsignificant, respectively.

CHAPTER 6

DISCUSSION

Weed suppression

One of the effects of ryegrass as a cover crop is its capacity to inhibit weed growth (Smith, 1994), both through competition (Stewart, 1996) and through allelopathy (Einhellig, 1986). In 1996, the fast growth of the ryegrass, as compared to the legumes, appeared to interfere with weed growth. The weed dry weight was significantly higher in those plots without ryegrass as compared to those with ryegrass.

As is often the case (Putnam, 1986), it is difficult to determine whether weed suppression is due to allelopathy, the chemical interference of one plant with the growth of another, or simply a case where, due to one plant's competitive advantage, it has monopolized the growing area. In this regard, it is interesting to note that the final percentages of ground cover of the cover crops were statistically indistinguishable. However, there was considerable difference in weed biomass, indicating that, in the ryegrass plots, there were more areas without cover crop which were bare soil than in the plots without ryegrass. This could be an indication that the ryegrass was allelopathically inhibiting growth in those areas.

Cover crop growth

Ryegrass also appears to have interfered with the growth of the leguminous cover crops when they were grown together. In 1996, there was a significant difference between the biomass of the red clover and ladino clover when grown separately and when grown with ryegrass. The same effect was seen in these covers as well as hairy vetch in 1997. Interestingly, there was also a significant difference in the ryegrass growth when grown separately and when grown with the legumes. Since the legume biomass, particularly that of the clovers, was relatively small (see discussion below), and since the legumes establish so much more slowly than the ryegrass, it seems unlikely that the reduction in ryegrass biomass is due to competitive effects. Past research efforts have found allelopathic effects of leguminous crops (Bradow, 1993). It is possible that these effects could explain the results here.

Any discussion of the results of these experiments must take into consideration the very small amount of cover-crop biomass that was generated compared to that found in the literature. Wagger (1989) reported an average dry weight of 4000 kg ha $^{-1}$ for hairy vetch and 4500 kg ha $^{-1}$ for crimson clover. Blevins (1990) obtained a dry-weight yield of 3400 kg ha $^{-1}$ hairy vetch. Sarrantonio (1994) has found that, in the Northeast, 3000-4000 kg ha $^{-1}$ is a typical harvest for hairy vetch. Liu (1997), at the South Deerfield Research Farm, obtained 6980 kg ha $^{-1}$ of cereal rye and 6790 kg ha $^{-1}$ hairy vetch. Mangan (1998), also at the South Deerfield Research Farm, achieved a hairy vetch yield of 2180 kg ha $^{-1}$ with a very early sampling date in late April.

These experiments all involved a fall seeding of cover crops, as opposed to the spring planting attempted here. This permitted regeneration early in the spring, considerably earlier than was possible in these trials, where the ground had to dry sufficiently to allow machinery to enter before it was possible to seed the cover crops.

Cover-crop nitrogen contribution

Among the legumes, there was a difference in both the accumulation of biomass and the percentage nitrogen in the plant tissue. In the first year, the field pea plots had the greatest dry weight accumulation but hairy vetch had the largest combination of biomass and percentage nitrogen, and so was the greatest nitrogen contributor.

It had both the greatest biomass accumulation and largest percentage nitrogen in the second year and so was the largest nitrogen contributor then as well.

The percentage nitrogen in the cover crops was consistent with the findings of other workers in the field (Holderbaum, 1990; Wagger, 1989; Ranells, 1996; Kuo, 1997). However, the paucity of cover-crop biomass is reflected in the correspondingly low total nitrogen contribution by the cover crops as compared to fall-seeded covers. While, in these trials, hairy vetch contributed, on the average, 70 kg ha $^{-1}$ nitrogen, Blevins (1990) obtained a nitrogen contribution from hairy vetch of 120 kg ha $^{-1}$, on the average, and Ranells (1996) found a contribution of 130 kg ha $^{-1}$ from hairy vetch. A comparable discrepancy is found in the figures for the clovers (Ranells, 1996; Holderbaum, 1990).

The figures show considerable nitrogen contribution by the grasses grown in conjunction with the legumes. While the grasses may be advantageous to physical properties of the soil (Abdul-Baki, 1996) and the nitrogen stored in the grasses may be an eventual benefit to crops (Fauci, 1994), the short term nature of this experiment makes it difficult to assess the benefits of ryegrass over the long term.

In 1997, the soil-nitrogen level was tested at the point at which sidedress nitrogen was to be applied. At this point, there should have been sufficient breakdown of the leguminous cover crops to see a difference in available nitrogen in the soil between the various treatments, if such a difference would exist at any time during the growing season (Liu, 1997). However, the differences among the various treatments were not statistically significant. While the trend toward higher nitrogen levels in the legume plots matches that of other trials (Kuo, 1997), the lack of statistical significance is probably due to the lower quantity of the incorporated matter here.

Corn yield

A similar problem is encountered in attempting to analyze the data obtained for corn yield. Corn yield, or the yield of any primary crop, is the standard method of determining the efficacy of different cultural methods in the field (Mitchell, 1977; Bruulsema, 1987; Blevins, 1990). While the statistical analysis of the corn crop yields some significant differences between the treatments, the importance of these differences and the validity of them must be called into question because the overall corn production levels were so low.

While the data in the literature regarding corn yield reflects a variety of circumstances and experimental designs, the resulting corn yields appear consistently and significantly higher than the results obtained here. Holderbaum (1990) obtained yields of 4200 kg ha^{-1} in the untreated plots, 8000 kg ha^{-1} in the fertilized plots, and 10,600 kg ha^{-1} in the plots with incorporated hairy vetch. Blevins (1990), depending upon the level of fertilizer, got between 3300 and 5200 kg ha^{-1} in the plots with hairy vetch, between 650 and 3900 kg ha^{-1} in the plots with ryegrass, and between 1040 and 4550 kg ha^{-1} in the fallow plots. These experiments involved corn grown early in the growing season. Begna (1997), growing a short-season corn in Quebec, depending upon spacing and density, obtained yields of between 3900 and 11,800 kg ha^{-1}.

The contrasts are striking. In 1996, the total corn dry weight in the fertilized plots, which normally would reflect standard practices, was 3800 kg ha^{-1}. This matches the very lowest yield obtained by Begna (1997) in the most disadvantageous planting pattern. It is only half the yield obtained under a similar fertilizer regime by Holderbaum (1990) and considerably less than that obtained by Blevins (1990). The highest yields, 4900 kg ha^{-1} in the hairy vetch and ladino clover plots, were still considerably less than those obtained in other trials. Corn ear dry weight figures are similar; at best, they are no more than one half the yield normally expected. (Mangan (1998) planted Harmony at the South Deerfield Research Farm at staggered planting times between April 24 and May 27. He obtained, for the lowest yield, 8,208 kg ha^{-1} dry weight of marketable ears, for the fallow plots, and, for the highest yield, 22,800 kg ha^{-1} dry weight of marketable ears for the treatments with hairy vetch and 156 kg ha^{-1} added nitrogen.)

The results in the 1997 experiment are even more problematic. The total corn plant yield of the fertilized plots was 2900 kg ha^{-1} and the largest yield of any treatment was 3600 kg ha^{-1} for the medium red clover with 156 kg N ha^{-1}. The largest yield of corn ears was 1400 kg ha^{-1}.

It is important to note that the low corn yield is not related to the low yield of the cover crops, although both contribute to the questionable usefulness of the experimental data. The control plots which were given normal fertilizer applications can be used as a benchmark against which the others are to be measured. Since the growth in these plots was substandard, the lack of overall growth must be attributed to factors outside the experimental design.

Keeping this caveat in mind, the data on the corn yield can be examined for the information it does reveal. It is possible, within this context and understanding the limitation of this study, to compare the different leguminous cover crops and the effect of ryegrass and added nitrogen fertilizer on subsequent corn yields.

Comparison of cover crops

Hairy vetch is a beneficial cover crop for enhancing corn yield (Holderbaum, 1990). In this study, when hairy vetch was planted alone, without added fertilizer, the corn output equaled or exceeded the regularly fertilized control plots. As Blevins (1990) found, added fertilizer tended to further increase yield. Consistent with Holderbaum (1990), however, ryegrass resulted in decreased yield. Added fertilizer can counteract the depressing effect of the ryegrass, however, and bring the yield levels up to and beyond that of the control group (Mitchell, 1977).

Medium red clover plots did not yield as much as the hairy vetch plots although they produced significantly more than the control plots across all levels (see also, McKenney, 1995). Unlike the vetch, they produced less corn when given no nitrogen than the control plots with nitrogen but were significantly more successful when given the same nitrogen and ryegrass treatments as the control plots. Since there was a significant increase in corn yield with the relatively small amount of clover that was incorporated in these trials, it is possible that, given more normal cover-crop yields, medium red clover alone could, like hairy vetch, give corn yield equivalent to the fertilized treatments.

The results of the ladino clover trials were different in the two years. In 1997, the ladino clover plots gave results which were statistically equivalent to the results for the red clover. In 1996, however, the ladino clover plots gave the highest corn yield of any plot, and higher than any plot in the 1997 experiment, even though total ladino clover dry weight in 1996 was 1100 kg ha^{-1} and in 1997 was 1300 kg ha^{-1}. These results are not explainable with the information available.

Comparison of ryegrass treatments

Differences in corn yield due to the presence or absence of annual ryegrass were striking. In both 1996 and 1997, the plots which contained ryegrass yielded significantly fewer total and marketable corn ears than the corresponding plots without ryegrass. This is consistent with the results of Decker (1994) and Wagger (1988), who tied the yield disparities to differences in available nitrogen. Schoenau (1996) found that grasses, due to their high carbon-to-nitrogen ratio, will immobilize available nitrogen when incorporated in the soil, making these reserves unavailable to the subsequent crop. The improvement in corn yield upon the application of nitrogen fertilizer to the ryegrass plots is consistent with a conclusion that low corn yield in the non-fertilized plots is due to a lack of available nitrogen.

Importance of this research

Although research such as this, with its small scope and short duration, cannot be considered conclusive evidence of any proposition, the results of this research should bring into question the efficacy of using spring-planted cover crops when they will be plowed under in mid-summer. A practitioner may find benefits which are separate from nitrogen accumulation by legumes, but cannot be assured that the nitrogen benefits will be forthcoming. More conclusively, this research questions the reliability of a sweet corn crop planted in New England in mid-summer. While the short-season variety planted did mature before the frost, the yield in marketable ears was so low as to make the venture unprofitable, at best. Further research into other corn varieties or other late season crops, such as brassicas, could produce results which would be more decisive and useful.

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